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**It does not occur by chance: a mediation model of the influence of workers' characteristics, work environment factors, and near misses on agricultural machinery-related accidents**

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(Article begins on next page)

1 **It does not occur by chance: a mediation model of the influence of workers'**  
2 **characteristics, work environment factors, and near misses on agricultural**  
3 **machinery-related accidents**

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## Abstract

Agriculture is among the most hazardous productive sectors, and farm machinery is a major source of injury. In the present study, a mediated model was used to test the role played by workers' characteristics, work environment factors, and near misses in predicting agricultural machinery-related accidents in a sample of Italian users ( $n = 290$ ). Hours worked per week (via the mediation of an adverse work environment) showed a positive association and years of work experience (via the mediation of risk perception) showed a negative association with the probability of being involved in a near miss, which in turn showed a positive association with the probability of being involved in a machinery-related accident. Implications for tailored preventive interventions are discussed.

Keywords: agriculture; near miss; occupational accident; risk perception; mediation model

## Introduction

With the mining and construction industries, agriculture is one of the three most hazardous productive sectors both in developing and industrialized countries [1], with an incidence rate of fatal accidents that is double the average of all other industries [2]. Based on data collected by the International Labour Organization (ILO) [3], in the EU-15, the incidence of fatal accidents in agriculture in 2005 was 0.8 per 10,000 farm workers. The corresponding incidence rate for the mining and construction industries was 0.5. For the US, the National Safety Council [4] reported that the mean fatality rate for the US agricultural industry from 1992 to 2002 was 2.23 deaths per 10,000 farm workers, whereas it was 0.39 per 10,000 workers for all US industries. Farm machinery is a major source of injury [5], and the highest number of fatalities involves tractors, mainly because of tractor rollover [6]. In the United States, Carlson et al.[7] reported 9.6 tractor-related injuries/1000 persons/year. A similar picture emerges in European Union countries [8] and particularly in Italy, where approximately 2,000 of 31,000 injuries that occurred in the agricultural sector in 2013 involved machinery, and 1,000 were tractor-related injuries [9].

49           The literature about occupational accidents shows that the occurrence of an accident involves  
50 multiple variables related to the individuals and their environment [10]. The same holds true  
51 regarding accidents in agriculture [11]. Two different classes of elements have been identified as  
52 the main predictors of being a victim of a farm accident: workers' characteristics and work  
53 environment factors. In addition to these two classes of risk factors, another powerful predictor of  
54 accidents is the so-called *near misses*, i.e., unplanned events that do not result in any injury, illness  
55 or damage only because of a fortunate break in the chain of events [12].

56   ***Workers' characteristics***

57   The main workers' characteristics are socio-demographic variables and those accounting for  
58 workers' relation with work [13]. Being an older farmer, working long hours, working alone, and  
59 operating on a large farm were found to foster the probability of being involved in farm injuries and  
60 fatal tractor overturns [14]. Furthermore, having a low risk perception has been shown to increase  
61 operators' exposure to occupational risks and accidents [15]. However, inconsistent results have  
62 been found in the literature with regard to the factors affecting risk perception, in particular relating  
63 to work experience and familiarity with tasks, machinery and equipment. In some studies,  
64 experience and familiarity were shown to reduce risk perception [16]. According to these studies,  
65 this occurs because familiarity may lead to overconfidence in the use of the devices: the lack of  
66 accidents in the person's history with the device contributes to the idea that 'I could do this with my  
67 eyes shut', thus reducing risk perception and the attention rate and increasing the probability of  
68 performing an unsafe behavior that may lead to an accident. For instance, a driver's accurate  
69 perception of the lateral tilt angle of a vehicle is an important factor in avoiding situations that may  
70 potentially lead to a side overturn. Görücü et al. [17], in their study addressing the perception of the  
71 lateral tilt angle of agricultural tractors, reported that older and more experienced participants  
72 disclosed higher limits of the lateral angle at which they felt uncomfortable and would not have  
73 driven the tractor. The result of this perception is depicted by the fatality statistics, which show that

74 older male operators usually represent a large percentage of tractor overturn victims [18]. Other  
75 studies, however, noted the opposite result [19]. According to them, individuals in familiar  
76 situations might be more likely to perceive the risks because they are more frequently exposed to  
77 the risky situation. This may increase compliance with safety practices and reduce the actual risk of  
78 accidents. Consistent with this, the results of an investigation of farmers' attitudes toward  
79 agricultural tractor innovations showed that the older the tractor users and the longer they had  
80 worked in agriculture, the higher their commitment to safe working conditions [20].

### 81 ***Work environment factors***

82 Work environment factors represent the second group of predictors of accidents. They account for  
83 workload and work organization [11]. Farm work exposes operators to a high workload due to a  
84 combination of different factors. Indeed, farmers usually work longer hours, and mostly alone, than  
85 workers in other occupations, and they must perform complex and varied tasks. They also handle  
86 different machinery that they must care for and maintain; furthermore, their work may be frequently  
87 interrupted by mechanical malfunctions – which occur especially in the case of old machinery – and  
88 visitors [13]. These adverse working conditions put high external pressure on farmers, increasing  
89 their fatigue and probability of being involved in an accident and being injured [21].

### 90 ***The near misses***

91 Near misses are at the lowest level of the safety pyramid model [22]. they occur more frequently  
92 and are smaller in scale than serious accidents, and each major accident is usually preceded by a  
93 number of near misses [23]. Near misses have been investigated in different sectors: road and rail  
94 traffic [24], plant engineering [25], building safety [26], home safety [27], and healthcare systems  
95 [28]. Less is known in the literature about near misses and their determinants in the agricultural and  
96 forestry sector than about other safety issues. Some exceptions are represented by the study by  
97 Lilley et al. [29], who showed that accidents among forestry workers in New Zealand were  
98 associated with having had near-miss injury events, and the literature review on accident prevention

99 by Lundqvist et al. [30], which included studies investigating near misses as a useful source of  
100 information about farm accidents. However, both the abovementioned studies considered near  
101 misses for their effects (accidents) rather than their determinants. Wright and Schaaf [24] showed  
102 that near misses and accidents substantially share the same determinants, confirming the idea that  
103 near misses may be considered a proxy of being exposed to the risk of suffering a more serious  
104 accident.

#### 105 *Motivations and aims of the present study*

106 Many statistics are available worldwide about accidents in the agricultural sector, their incidence,  
107 and the characteristics of the injured workers [1]. Less is known, however, about the processes and  
108 the relationships between the critical variables leading to an accident. The two different classes of  
109 risk elements identified in the literature (workers' characteristics and work environment factors) and  
110 their role in predicting the probability of being involved in an accident have systematically been  
111 investigated by analyzing survey data with multiple regression models [11,13]. Such models are  
112 undoubtedly fruitful. However, they force the researcher to consider all the predictors considered in  
113 the study at the same hierarchical level without taking into account that some variables may  
114 simultaneously be predictors of some and outcomes of other variables.

115       Regarding this aspect, the review of the literature showed that many variables are involved  
116 at different levels in the onset of a farm accident. Experience has an influence on risk perception  
117 (though previous results are not consistent regarding the direction of such influence: see  
118 McLaughlin et al. [16]; Rogers et al. [19]), and risk perception in turn affects the probability of  
119 being involved in occupational accidents [15]. In addition, working for longer hours, alone, and on  
120 a large farm has been shown to increase workers' exposure to adverse work environment factors  
121 [14]. These are conditions that can trigger near misses [31] and accidents [18]. Therefore, we  
122 assumed that the processes leading to farm accidents may be more suitably investigated by adopting  
123 a mediation model instead of a multiple regression model. In addition, we assumed that the model

tested should include the near misses, which have been reported as important predictors of accidents [12] but nonetheless have been under-investigated in previous studies of accidents in agriculture.

Based on these considerations, the present study aimed to investigate the risk factors for agricultural machinery-related accidents in a sample of Italian users, examining the role played by a) workers' characteristics, b) work environment factors, and c) near misses and adopting a mediated model to test the seven different hypotheses (Hs) described hereafter.

Based on Myers and Hendricks [13] and on Hwang et al. [14], we expected working alone (H1), farm size (H2) and working hours (H3) to show a positive association with the exposure to adverse work environment factors. Concerning the relation between years of work experience and risk perception, because of the inconsistent results available in the literature, we made two alternative competing hypotheses. If—as in McLaughlin et al. [16]—work experience leads mainly to overconfidence in the use of devices, it should show a negative association with risk perception (H4a); in contrast, if work experience—as in Rogers et al. [19]—leads mainly to an increased situational awareness, it should show a positive association with risk perception (H4b).

Furthermore, based on Kogler et al. [31] and on Elkind [15], we postulated that exposure to adverse work environment factors would show a positive association (H5) and risk perception would show a negative association (H6) with near misses. Finally, based on Phimister et al. [23], we expected near misses to show a positive association with being involved in an accident (H7). We analyzed such relations via a mediated model rather than a standard regression to account for the complexity of the associations we hypothesized, with accidents being the outcome of the model; working alone, farm size, hours worked, and years of experience being the predictors (i.e., the exogenous variables); and adverse work environment, risk perception, and near misses being mediators (i.e., outcomes of working alone, farm size, hours worked, and years of experience and at the same time predictors of accidents).

## **Method**

149 ***Participants and setting***

150 The study involved a sample of 290 users of agricultural machinery (272 men,  $M_{\text{age}} = 45.46$  years,  
151  $SD = 17.40$ ). The participants worked an average of 39.67 hours per week ( $SD = 23.72$ ) and had  
152 been working in agriculture for 26.45 years ( $SD = 18.00$ ).<sup>1</sup> Participants' distributions of gender,  
153 age, education, and occupation were in line with those of the Piedmont and Italian agricultural  
154 population, as reported in the VI Agricultural Census of 2010 [32,33]. They were recruited from the  
155 visitors to the 35th National Exhibition of Agricultural Mechanization in Savigliano, the largest  
156 agricultural machinery exhibition in the Piedmont region (northwestern Italy). The 2016 edition of  
157 the show (18-20 March) was attended by over 65,000 visitors. The Piedmont region, one of the  
158 twenty Italian regions, covers 35% of the Po River catchment, with agriculture taking place on the  
159 plain (41% of the utilized agricultural area – UAA), mainly maize-based systems, and on the hills  
160 (31% of the UAA), mainly vineyards and winter cereals [34]. The Piedmont region is a good  
161 representation of the Italian farming system and rural population since it includes approximately  
162 10% of the total Italian UAA. Moreover, over 61,000 of the 1,620,884 Italian agricultural holdings  
163 operate in this region [32].

164 Since the agricultural population is spread across the country and has varying operating  
165 schedules, agricultural machinery exhibitions are one of the few occasions at which a large and  
166 wide-ranging group of agricultural workers comes together. Such events therefore provide a  
167 suitable location for appropriate surveys and other data-collection activities [17,35].

168 ***Instrument***

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<sup>1</sup> As shown in Table 1 (see below), in our dataset, participants' age and years of experience in agriculture showed a very strong correlation. To avoid an excessive conceptual overlap and problems of empirical collinearity, both in the theoretical and in the empirical sections of the paper, we reasoned in terms of years of experience rather than in terms of age.



169 A 27-item self-administered paper-and-pencil questionnaire was used to gather information about  
170 participants' work environment, risk perception, near misses, and accidents. The different sections  
171 and items of the questionnaire were designed based on previous instruments [11,29] and on the  
172 evidence from a preliminary qualitative study [36]. Risky machinery-related tasks and types of  
173 accidents and near misses were selected after an analysis of the statistics regarding the most  
174 frequent and serious machinery-related accidents and injuries in Italian agriculture [9]. The  
175 questionnaire was pilot-tested with a group of 8 operators before being submitted to the sample of  
176 the present investigation.

177 The questionnaire was composed of 3 sections. In the first section, participants were  
178 administered a list of 4 adverse work environment factors: sufficient manpower (con-trait),  
179 interruptions by machinery malfunctions, interruptions by on-farm visits, and work delay due to the  
180 adoption of safety measures. Participants were asked to rate on a 4-point scale (1 = never, 4 =  
181 always) how often these 4 situations occurred on their farm. The 3 items related to manpower and  
182 interruptions came from Glasscock et al. [11], whereas the adoption of safety measures was  
183 indicated by farmers as often causing work delays and thus increasing time pressure in agricultural  
184 tasks in a preliminary qualitative study [36]. A confirmatory factor analysis (CFA), performed after  
185 reversing the first item, showed that the scale was unidimensional,  $CFI = 1.00$ ,  $IFI = 1.00$ ,  $RMSEA$   
186  $= .00$  (90%  $CI = .00, .08$ ).<sup>2</sup>

187 In the second section, participants had to report on a 4-point scale (ranging from 1 = not  
188 risky at all to 4 = very risky) how risky they considered the following tasks in machinery  
189 operations: moving equipment near power lines, manually feeding a wood chipper, using a wood-  
190 splitting machine/circular saw, using the tractor on a field without a seatbelt, handling round bales

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<sup>2</sup> We tested the unidimensionality of this and the next scale using CFA instead of Cronbach  $\alpha$  because the strength of the latter depends, beyond their mean correlation, on the number of items, and our first battery was composed of only 4 items.

191 with a front-end loader, working with machinery near ponds or ditches, cleaning a manure spreader  
192 while it is in motion, and descending from the tractor without turning the engine off. Items about  
193 power lines and working near ponds were taken from Whitman and Field [37], whereas the other  
194 items were operations or tasks that are more likely to lead to an accident according to Italian  
195 national safety statistics [9]. A CFA showed that the scale was unidimensional,  $CFI = .93$ ,  $IFI = .93$ ,  
196  $RMSEA = .05$  (90%  $CI = .00, .09$ ). Participants' scores on these scales were computed as  
197 standardized factorial scores.

198 In the third section, participants had to indicate how often in the 12 months preceding the  
199 survey they had been involved in 5 different types of events involving agricultural machinery, using  
200 a 3-category format (0 = never; 1 = once; 2 = twice or more): fall/thrown from a vehicle; run  
201 over/crushed by a vehicle; struck by flying objects, broken parts, or hydraulic fluid; side/rear  
202 rollover; and road accident with tractor/equipment. Participants were asked to answer the battery  
203 twice, reporting for each event how often they had been involved with (i.e., accident) and without  
204 (i.e., near miss) suffering an injury. The list of events was created based on the most common types  
205 of accidents involving agricultural machinery according to the statistics from the Italian Workers'  
206 Compensation Authority [9]. After dichotomizing participants' answers (contrasting the 0 and the  
207 other responses), we computed two scores as sums of their responses to the first and to the second  
208 version of the batteries that were used as operationalization of the number of accidents and of near  
209 misses occurring in the 12 months preceding the survey. A standard socio-demographic form  
210 assessing participants' relation with work (hours worked per week, years of experience in the  
211 agricultural sector, farm size and whether they were a sole farmer) ended the questionnaire.

## 212 ***Procedure***

213 Trained research assistants handed out the questionnaire to people walking through the exhibition.  
214 They approached visitors and asked whether farming was their primary or secondary occupation  
215 (i.e., being a part-time farmer) and whether they used agricultural machinery at least once a week.

216 In the case of a positive answer, the assistants explained the aims of the study and informed the  
217 participants that the questionnaire was anonymous. The questionnaire was in Italian, and its  
218 completion took approximately 6-7 min. No incentive was offered to induce visitors to participate  
219 in the survey. The response rate was approximately 85%.

220 **Results**

221 Table 1 reports the descriptive statistics for the variables that the study investigated and the  
222 correlations among them. Of the participants, 45.9% had been involved in at least an accident and  
223 44.8% had been involved in at least a near miss in the 12 months preceding the survey.

224 ---Table 1 about here---

225 A first path analysis model showed that H1 and H2 were falsified. Indeed, being a sole  
226 farmer ( $b = .04$ ,  $SE = .12$ ,  $p = .74$ ) and the size of the farm where the participant worked ( $b = .00$ ,  
227  $SE = .00$ ,  $p = .13$ ) showed no significant association with adverse work environment. Thus, we re-  
228 ran the model after deleting those variables. All the paths of the resulting model were statistically  
229 significant (see Figure 1: betas and standard errors are displayed). The hours worked showed a  
230 positive association with working in an adverse environment ( $R^2 = .06$ ), confirming H3. Consistent  
231 with H4b and contrary to H4a, years of experience showed a positive association with risk  
232 perception ( $R^2 = .08$ ). Consistent with H5 and H6, working in an adverse environment and risk  
233 perception, respectively, showed a positive and a negative association with near misses ( $R^2 = .07$ ),  
234 which in turn, consistent with H7, showed a positive association with accidents ( $R^2 = .08$ ). Table 2  
235 shows that all the indirect effects we tested, even the small ones, were significant. The fit of the  
236 model was satisfactory,  $\chi^2(9) = 16.44$ ,  $p < .06$ ,  $IFI = .92$ ,  $CFI = .92$ ,  $RMSEA = .05$  ( $CI = .00, .09$ ).<sup>3</sup>

237 ---Figure 1 about here---

238 ---Table 2 about here---

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<sup>3</sup> Parallel analyses, performed by substituting participants' years of experience in agriculture for their age, showed analogous results (available upon request).

## 239 **Discussion**

240 The present study investigated, via a mediation model, the risk factors for machinery-related  
241 accidents in the agricultural sector. The model showed that workers' characteristics are associated  
242 with exposure to adverse work environment factors and risk perception, which in turn are associated  
243 with the probability of being involved in near misses and accidents. Consistent with the literature  
244 about occupational accidents [10], in the present study, different variables were shown to be  
245 interwoven in the occurrence of an agricultural machinery-related accident.

246 Our mediation model noted the more critical variables and at what level they affect the chain  
247 of events leading to accidents, suggesting that machinery-related safety issues be addressed by an  
248 ergonomic approach ([www.iea.cc](http://www.iea.cc)) This approach considers the individuals in their interaction with  
249 the proper tools and tasks of their work environment and allows interventions to be developed in  
250 different dimensions (materials vs. practices) and at different levels (individual level vs. farm level)  
251 [38] to find the best fit between the worker and the job in terms of health, safety, comfort, and  
252 performance [21].

253 The results of the study showed that regarding workers' factors, working long hours  
254 increased the exposure to accidents through the mediation of adverse working situations, such as  
255 interruptions and time pressure. A positive association between hours worked and involvement in  
256 accidents has already been noted by previous studies both in the agriculture/forestry sector [29] and  
257 in other industries [39]. When an operator works long hours, he/she is likely to address many  
258 different situations, which increases fatigue and reduces alertness, causing errors and thus  
259 enhancing the possibility of being injured in an accident [40]. Interventions addressing this issue  
260 may focus on redesigning the work process [41], for instance, by training workers to take  
261 systematic rest breaks during their working hours [38] or assisting farmers in managing external  
262 pressures [18].

263           The worker's experience is another critical workers' factor that, according to the results of  
264 the model we tested, enhances risk perception. The outcome of the study contributes to the  
265 discussion of the consequences of familiarity with tasks and machinery [16,19], strengthening the  
266 assumption of the protective role of this variable. A lack of accidents or near misses in a person's  
267 history with a device/machine has been reported to lead to overconfidence in its use and lower risk  
268 perception [16]. Similarly, it is reasonable to assume that previous exposure to near misses and  
269 accidents is responsible for the positive association between work experience and risk perception  
270 found in the present study. In this light, the longer the operator has been working in the field, the  
271 more accidents and near misses he/she may have encountered, learning from these events and thus  
272 increasing his/her risk awareness and perception [42].

273           The study showed that higher risk perception predicts lower occurrence of near misses and  
274 accidents. Risk perception is thus confirmed to play a crucial role in the occurrence of accidents  
275 [15], suggesting further investigation, especially in such a hazardous sector as agriculture.  
276 Identifying factors that lead to a higher risk perception in agricultural operators will allow the  
277 development of training interventions and information campaigns tailored to maximize their  
278 preventive effectiveness.

279           In the present study, near misses appeared to be a significant predictor of accidents. This  
280 result confirms the importance of investigating near misses to prevent more serious accidents [12],  
281 including in the agricultural sector, in which near misses have been largely neglected. Farmers may  
282 be trained to recognize and annotate near misses to early identify critical aspects leading to  
283 accidents and intervene to eliminate or reduce them. According to Kogler et al. [31], the main  
284 preventive measures indicated by farmers to help them avoid near misses are, in order of  
285 importance, increased training in agricultural operations, mechanical adaptations, and easy-to-  
286 understand and short written operating instructions. Regarding the importance of training, the  
287 evidence by Burke et al. [43] raises some considerations about the need to adopt not only such

288 conventional training methods as pamphlets, lectures, and videos but also more engaging behavioral  
289 modeling techniques – such as hands-on demonstrations and behavioral simulations – to promote  
290 the correct and safe use of machinery and therefore reduce accidents.

291 Clear and short operating instructions, such as use and maintenance manuals, and clear and  
292 effective safety information about machinery, such as pictorial representations, are additional  
293 important elements to promote the safe use of machinery. Operator manuals are supposed to be an  
294 exhaustive source of information for the safe use and maintenance of agricultural machinery, but  
295 previous studies have shown that they are often unread [44] due to poor document design, requiring  
296 a non-negligible cognitive load to decipher pages packed with information that is mainly intended  
297 for the legal protection of the manufacturer. Pictorial representations affixed to machinery are visual  
298 tools to convey relevant safety information, but they are not as effective as they are supposed to be  
299 [45,46]. A re-design of these sources of safety information must be considered to enhance safety in  
300 machinery use.

301 Contrary to the findings of previous studies [13,14] no significant associations between  
302 being a sole farmer and farm size on the one hand and exposure to accidents on the other hand  
303 emerged. Accidents occur in all types of farms of any dimension and to all kinds of holders: safety  
304 interventions and campaigns should therefore address all kinds of farms and farm operators without  
305 considering some groups more at risk than others.

#### 306 *Limitations of the present study and possible research developments*

307 Some limitations of the present study should be acknowledged. The survey was carried out in the  
308 Piedmont region of northwestern Italy. On the one hand, the Piedmont farming system is a good  
309 representation of Italian agriculture, and performing the study at a local level allowed us to test a  
310 parsimonious model: participants in the study had a similar cultural background; thus, we could  
311 manage comparable data without controlling for a plethora of socio-demographic variables [47].  
312 Even though the socio-demographic characteristics of our participants were in line with those of the

313 Italian rural population reported in the last agricultural census, it is apparent that only the people  
314 who attended the Exhibition of Agricultural Mechanization in Savigliano could participate in our  
315 survey. More generalizable results would be available from a random sample of agricultural  
316 workers.

317 Another limitation is that our data on near misses and accidents were based solely on self-  
318 reports, and the recall covered quite a long period (12 months). Even though self-reporting is a quite  
319 common strategy in this kind of investigation [29,48], and 12 months is the usually considered  
320 period [11], it is possible that the participants' responses were affected by memory bias, thus  
321 resulting in a gap between self-reported and actual involvement in the reported events [49]. To  
322 obtain more accurate information about these variables, a possible direction of study would be to  
323 register near misses and accidents weekly (as for the accidents studied in Glasscock et al. [11]).

324 Finally, it should be noted that the bivariate correlations between our variables were not  
325 very strong, like the variance of the dependent variables we have explained. Moreover, consistent  
326 with Chaplin [50], the indirect effects that we detected were small. The weakness of these effects  
327 may likely be attributed, at least in part, to methodological rather than theoretical reasons. Indeed,  
328 as we performed field research, we could measure our variables using short scales; thus, we had to  
329 manage measures that were plausibly distorted, at least in part, by measurement error. Stronger  
330 indirect effects will likely stem from new research performed using longer scales.

331 Possible future developments of the research could further explore the relationship between  
332 adverse work environment factors and accidents, considering the safety behaviors [11] and coping  
333 strategies adopted when dealing with adverse and stressful conditions [51] as mediators of the  
334 relationship. Moreover, it would be interesting to increase our understanding of the factors  
335 contributing to farm accidents in two ways: first, via more objective techniques of data collection,  
336 such as the observation of farmers interacting with different machines, to identify risky behaviors  
337 that can increase the probability of being involved in an accident (as in Mann et al., [52]), and

338 second, taking directly into account the issue of the age of agricultural machinery, which is known  
339 to play a role in the onset of agricultural accidents [53]. The use of aging machines with inadequate  
340 safety engineering represents a constant source of risk, as operations involving high numbers of  
341 disturbances, e.g., machinery breakdowns, have a higher accident probability [54]; our  
342 questionnaire item about frequent interruptions of farm work due to machinery malfunctions was  
343 based on this evidence. However, the age of machinery could be explicitly assessed as a factor that  
344 could affect the mediators or the outcomes of our model.

345 Furthermore, the reasons underlying the positive association found in the present study  
346 between work experience and risk perception could be further investigated. For instance, a farmer's  
347 previous history of near misses and accidents could be evaluated and added as a mediator in the  
348 relationship between experience and risk perception, or expert and novice farmers could be  
349 observed/interviewed when interacting with machinery to identify the ways in which they perform  
350 their complex and varied tasks and the different strategies adopted to reduce risks (as in Mann et al.  
351 [52]).

352 Furthermore, in future research, data collection on farm accidents and near misses could be  
353 extended over a longer period. This would allow researchers to investigate the possible mediation  
354 effects of previous exposure to such events on the relationship between work experience and risk  
355 perception [42]. Finally, a mediation model such as the one used in the present study could be  
356 adopted to investigate accidents related to livestock [55] and pesticides [56], which are other major  
357 causes of accidents and health issues in the agricultural sector.

## 358 **Conclusions**

359 The chain of events leading to an occupational accident deserves particular attention in agriculture,  
360 due to the high hazardousness of this sector. The results of the present study showed that different  
361 critical variables intervene at different levels in determining an agricultural machinery-related  
362 accident. Hours worked and work experience affected the probability of being involved in an



363 accident through the mediation of adverse work environment and risk perception and then of near  
364 misses. These results suggest that different facets of the interaction between the operator and his/her  
365 work environment should be considered when designing preventive interventions, ranging from a  
366 re-design of the actual work processes to the development of strategies to enhance workers' risk  
367 perception. Interventions should also focus on near misses, making the reporting and analysis of  
368 these events a widespread and systematic practice among farmers and farm workers [12].  
369 Furthermore, interventions should support the protective role played by work experience by  
370 adopting engaging training methods as behavioral modeling in the use of machinery to optimize the  
371 learning of safety practices and safe behaviors. Finally, it must be noted that, as found by Kogler et  
372 al. [31] with regard to near misses, any solution and intervention aimed at improving the quality of  
373 farmers' work life and reducing accidents must also be disseminated to the farming populations in  
374 formats that are acceptable and understandable [21].

375

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Table 1. Descriptive statistics for the variables we used and correlation among them

	Mean	SD	1	2	3	4	5	6	7	8	9
1. Worked hours per week	39.67	23.76	-	-.15*	-.12*	.28***	-.19***	.24***	-.13*	-.07	-.03
2. Age	45.47	17.40		-	.82***	-.14*	.29***	-.18**	.23***	-.10	-.08
3. Years of experience in agriculture	26.45	18.00			-	-.10	.22***	-.11	.23***	-.12*	-.10
4. Farm size (ha)	33.83	53.40				-	-.18**	.15*	-.10	-.05	-.06
5. Sole farmer (0 = no, 1 = yes)	.37	.48					-	-.04	.12*	-.03	.01
6. Adverse work environment	0.00	1.00						-	.01	.13*	.15**
7. Risk perception	0.00	1.00							-	-.13*	.09
8. Near misses	1.11	1.71								-	.97***
9. Accidents	0.99	1.52									-

*Note.* The “mean” of being a sole farmer is the proportion, on a 0-1 scale, of the participants who reported to be a sole farmer. When being a sole farmer is involved, the point-biserial correlation coefficient is displayed. \*\*\*  $p < .001$ . \*\*  $p < .01$ . \*  $p < .05$ .

1 Table 2. Indirect effects of the exogenous variables and of the mediators.

	Years of experience in agriculture	Worked hours per week	Risk perception	Adverse work environment
Risk perception				
Adverse work environment				
Near misses	-.00*	.01**		
Accidents	.00**	.00**	-.23**	.00**

2 *Note.* \*\*  $p < .01$ . \*  $p < .05$ .



3    Figure caption

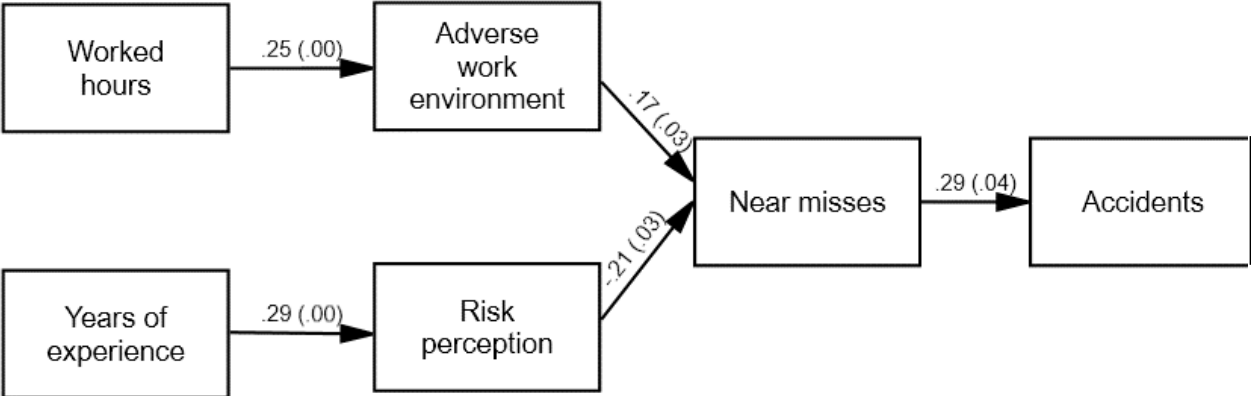
4    Figure 1. Workers' characteristics predict accidents through the mediation of adverse work  
5    environment, risk perception, and near misses.

6

7

8

9    Figure 1



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11